# Final Design and Initial Pulsed Power Results for the Decade Quad Plasma Radiation Source Machine Configuration*

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*Abstract*

At the 1999 IEEE Pulsed Power Conference, we reported on the preliminary design of a water coupler system that would combine the current from four individual Decade modules to drive a single plasma radiation source. The design has been finalized; the hardware has been fabricated and fielded on the Decade Quad at the Arnold Engineering Development Center. The final design issues associated with fabrication of the hardware and initial results into a short circuit load and imploding aluminum wire arrays are presented. We also present initial test results with the Decade Quad in the large area bremsstrahlung mode.

## I. BACKGROUND

The DECADE Quad (DQ) Large Area Bremsstrahlung (LAB) mode, shown in Figure 1, became operational in August 1999. Four independent modules drive separate, closely packed bremsstralung diodes.[1] Each oil-insulated Marx generator stores 1.4 MJ and discharges in about 1 μs. Water transfer capacitors and triggered gas output switches are employed to compress the pulse to a ≈300 ns quarter cycle. A final stage of pulse compression is provided by plasma opening switches in the vacuum MITLS after the water output lines. Initial tests on the Decade Quad in LAB mode demonstrated an area-weighted dose of 16.2 krad(Si) with:

- End-point Energy of 1.7 MV
- Pulse width of 35 ns
- Area of 2,250 $cm^2$ @ 2.8:1 uniformity

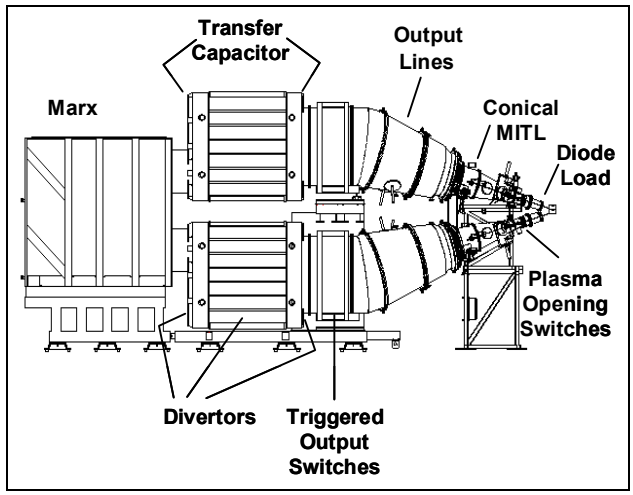


Figure 1. DECADE Quad in the Large Area Bremsstrahlung configuration.

During a subsequent test series led by AEDC, the power flow geometry between the plasma opening switch and the diode load was modified, resulting

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14. ABSTRACT
**At the 1999 IEEE Pulsed Power Conference, we reported on the preliminary design of a water coupler system that would combine the current from four individual Decade modules to drive a single plasma radiation source. The design has been finalized; the hardware has been fabricated and fielded on the Decade Quad at the Arnold Engineering Development Center. The final design issues associated with fabrication of the hardware and initial results into a short circuit load and imploding aluminum wire arrays are presented. We also present initial test results with the Decade Quad in the large area bremsstrahlung mode.**

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in improved current transfer to the radiation source. Data from operation in the LAB mode indicate that the pulse power driver elements (Marx generator, transfer capacitors, MITLS, and plasma opening switches) operated as expected. Details on LAB mode operation can be found in Paper O5B1 entitled, "Improved Large Area Bremsstrahlung Performance of the Decade Quad," by Babineau, et al. [2]

## II. PRS DRIVER DESIGN

In order to provide the Decade Facility with a cold x-ray source a design for combining currents to drive a plasma radiation source (PRS) was commissioned. The design goals for a PRS driver were:

- Current output of greater than 10 MA peak into a short-circuit load and greater than 8 MA into a ≈300 ns imploding PRS load. Capability of driving future monolithic plasma opening switches for use in both PRS and bremsstrahlung output modes.
- Consistent with the (future) installation of a 10-cm-diameter uniform-fill gas-puff PRS load.

As reported at the 1999 Pulse Power Conference, the design shown in Figure 2 combining currents from each module in a water coupler was selected. [3] The electrical power from the four output line modules is carried through four interface spools and combined in a triplate, conical, water-filled coupler. The power flows through a high voltage insulator stack, onto triconic MITLs, through a post-hole-convolute (PHC) and finally to conical load. The conical coupler design provides 90° line-of-sight access to imploding plasma radiation through twelve ports around the circumference of the user chamber.

Figure 3 displays more details of the coupler design. Based on this design the simplified circuit model shown in Figure 4 was developed.[4] Analysis of the model indicated that the design would meet the design goals of 8 MA into a 300 ns imploding plasma load while maintaining acceptable breakdown margins in the water transmission lines, on the diaphragms in the water lines, at the insulator stack, and in the vacuum MITLs.

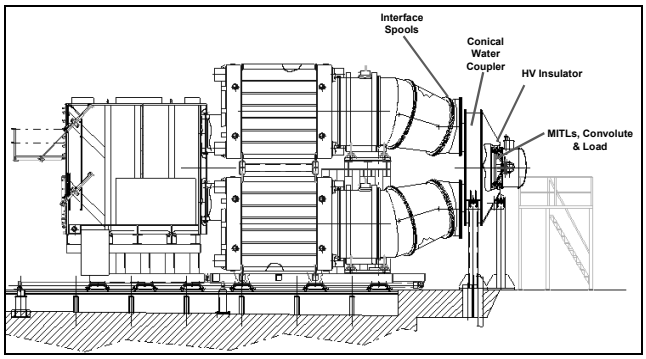


Figure 2. The Decade Quad in the PRS mode.

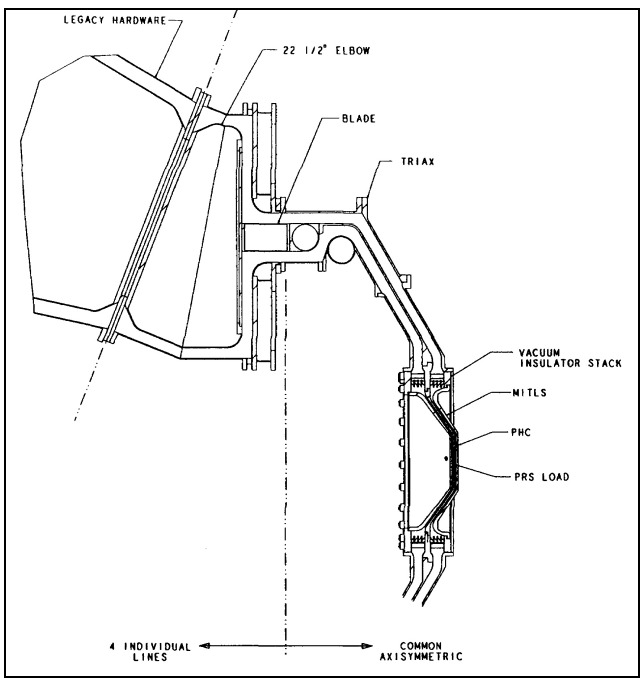


Figure 3. Details of the water coupler design. The 3 m diameter, 3000 kg annular cover and the 1 m diameter test chamber are not shown.

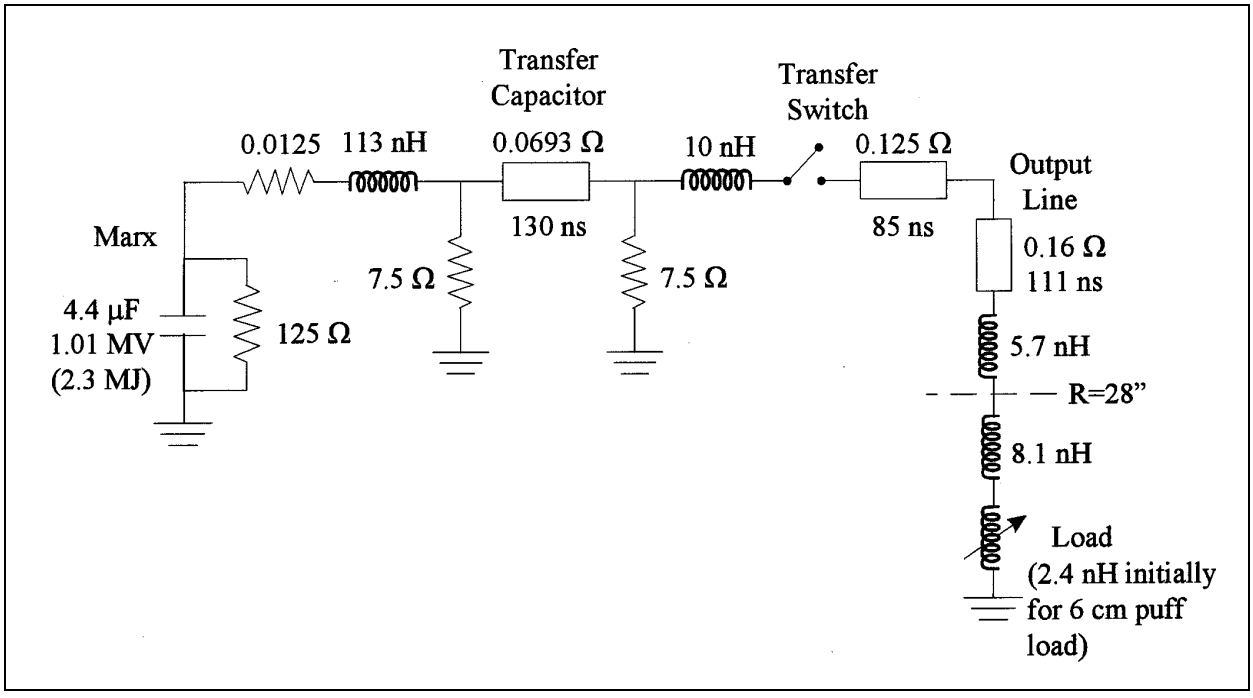


Figure 4. Simplified version of circuit model from reference [4] used to predict DQ PRS performance.

## III. PRS DRIVER REALIZATION

In fabrication, there was a significant distortion of the rear outer anode cone. In a welding operation, the angle of the cone "flattened" from about 30 degrees to about 29 degrees. Fabricating a replacement part that was "to print" would have added a 6 to 9 month delay to the fabrication schedule. We elected to use the part with minor modifications and change adjacent parts to retain critical electrode separations that control impedance, inductance, and electrical breakdown strength. This resulted in shortening the water coupler about 1/2 inch. Analysis of the mechanical changes indicated no degradation in expected electrical performance.

The hardware was delivered and assembled at AEDC in the fall of 2000. Figure 5 shows the water coupler attached to the modules.

## IV. PRS DRIVER PERFORMANCE

Water coupler performance was demonstrated with short-circuit and over-massed wire aluminum loads. Short-circuit loads tests performed at 65 kV Marx charge voltage scaled to the required 10 MA at a full Marx charge

Figure 5. Decade Quad in PRS Mode

voltage of 85kV. Data from an over-massed aluminum wire shot is. Calculated and measured output currents into an imploding aluminum wire array at full power (85 kV Marx charge voltage) are shown in Figure 6. Itube and Iload were measured and match the calculated tube, MITL, and load currents very well up until the peak current. The peak current reaches 9 MA in about 250 ns, exceeding the design goal. Any changes in electrical performance caused by the differences between the design and the fabricated parts were undetectable. The water coupler design is now

available to support development of PRS radiation sources and plasma opening switches for driving bremsstrahlung loads at currents in the 8 to 10 MA and 250 to 300 ns range.

## V. REFERENCES


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[3] D. Price, M. Danforth, T. Naff, T. Tucker, P. Sincerny, P. Spence, P. Corcoran, R. Altes, V. Bailey, J. Douglas, D. Fiely, and K. Ware, "Electrical and Mechanical Design of the Decade Quad in the PRS Mode," in Proc. Twelfth IEEE Intl. Pulse Power Conf., Monterey, CA, 1999, p. 489.

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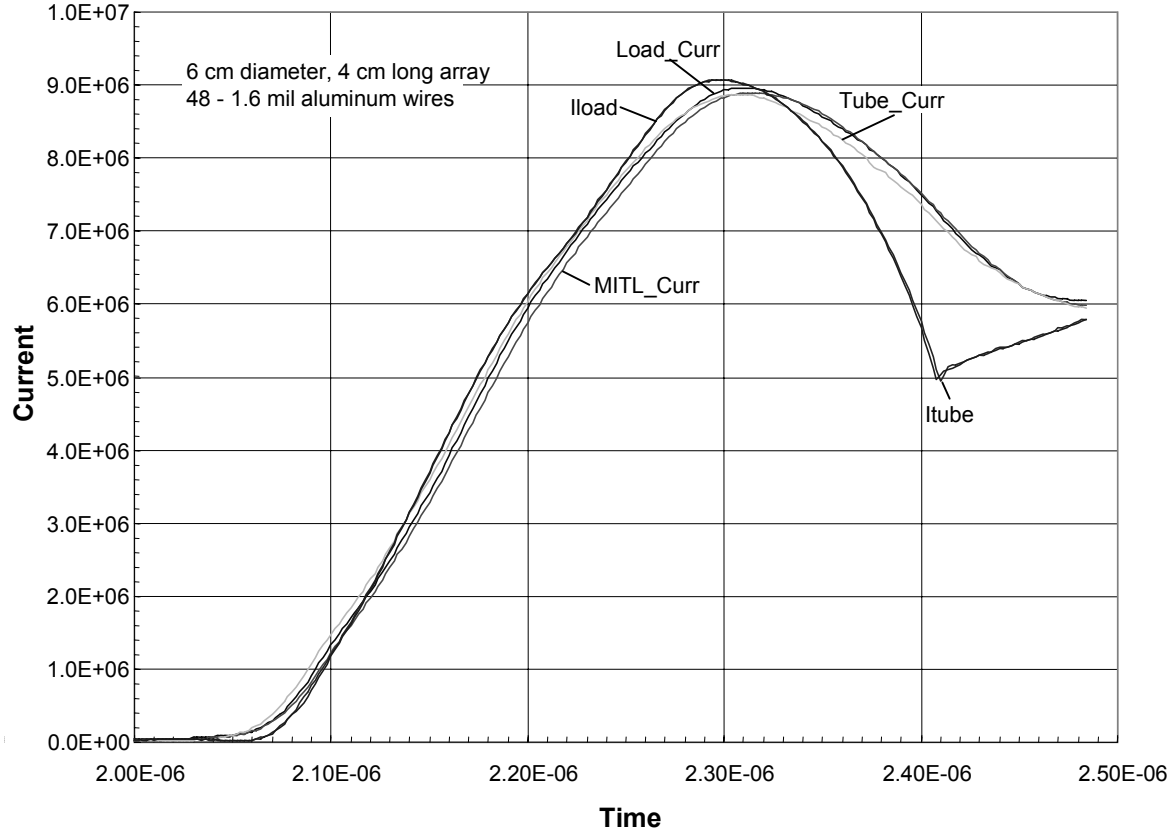


Figure 6. Calculated and measured output currents into an imploding aluminum wire array at full power (85 kV Marx charge voltage).